

Not only range, but quality: human influence and protected areas within the distribution of mammal species subject to use in the Department of Cundinamarca, Colombia

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Abstract

Mammal conservation in transformed landscapes depends heavily on the role of protected areas, especially for species used by local communities both within and around these areas. We evaluated the level of representation and the magnitude of the influence of humans, via human footprint, across the range of mammals used by local communities in the Department of Cundinamarca, Colombia. We emphasised the differences of the human influence at a department scale and inside Protected Areas (PA). The definition of species used by local communities refers to using a resource for its economic, religious and/or traditional value. Specifically, we addressed whether there is a difference between the magnitude of human influence inside and outside the PAs and if the impact is greater on threatened species, species with greater or lesser representation or according to their use. We found 43 species subject to use in our analysis, with low values of representation when compared with global targets ($\bar{X} \pm \text{CD} = 10.69\% \pm 4.99$) and with high values of vulnerability, based on the mean value of the Spatial Human Footprint Index (HSFI) (57 ± 2.74). We found a difference of 10.72 points between the average HSFI of the Department and that of the PAs ($\bar{X} \pm \text{CD} = 10.73 \pm 5.98\%$). This shows that the status of each species' habitats is less impacted by hu-

man activities within PAs and that the conservation areas for all species depend largely on their presence in largely transformed landscapes. Although this seems an expected outcome, the Department of Cundinamarca is one of the less represented on PAs at a national level and has suffered from severe fragmentation; thus, our results highlight the need for improving and expanding the current PA system as most species, especially those subject to use, will depend on their existence for their conservation on the long run.

Keywords

Andes, human footprint, Protected Areas, species modelling, species range

Introduction

Mammals are one of the main groups widely used to assess landscapes and ecosystems' ecological integrity and health in different parts of the world (Rondinini et al. 2011; González-Maya et al. 2015; Di Minin et al. 2016; González-Maya et al. 2016). This largely responds to their role in the functioning and maintenance of ecosystems, which supports its use for conducting conservation status assessments (Aubry et al. 2003; Prugh et al. 2009; Ripple et al. 2014). Mammals stand out for their ability and capacity to disperse seeds, maintain the balance of trophic chains and their role as soil fertilisers and pollinators, amongst many others (Aubry et al. 2003; Noss et al. 2012; Lacher et al. 2019). Likewise, they have been widely used to understand protected areas (PA) status, connectivity and conservation contribution, particularly when analysing at landscape scales (Beier 1993; Cullen et al. 2013; Zárrate-Charry et al. 2018).

Even when mammal species provide a diversity of ecosystem services, they are one of the most threatened taxonomic groups globally due to the loss of their habitat, overexploitation, climate change among others (Schipper et al. 2008). These pressures, that overall affect biodiversity in general, are considered severe for many mammals since most of them have high energy requirements, usually depending on quality habitats and abundant resources (Schipper et al. 2008; Ripple et al. 2014); although some species might tolerate certain levels of intervention, overall, mammals require habitats and resources which in general make them good ecological indicators (Sinclair 2003; Schipper et al. 2008; Pineda-Guerrero et al. 2015; González-Maya et al. 2017). In addition to being one of the most important groups of animals for most ecosystems, mammals are also one of the groups most directly used by human communities (Cortés-Gregorio et al. 2013; Ripple et al. 2014; Van Vliet et al. 2015). From a sociocultural perspective, they are not only a tangible resource, object of appropriation and the basis of various recreational, cultural and subsistence needs, but they are also part of the collective imagination of intangible forms, whether associated with myths, legends, art or folklore, even contributing to the identity of various peoples and communities (Vargas-Clavijo 2008; Vargas-Clavijo 2009).

Along with the many strategies for mammal conservation, various management actions have been designed, ranging from conservation plans (Castaño-Urbe et al. 2013; Ministerio del Ambiente and Wildlife Conservation Society 2014), strategies

for sustainable use of species or landscapes (Fischer et al. 2010; Sims and Alix-Garcia 2017) and strategies for landscape conservation, for which Protected Areas (PAs) continue to be one of the main pillars (Stolton and Dudley 2010; González-Maya et al. 2015; Di Minin et al. 2016; Zárrate-Charry et al. 2022). PAs are an essential tool for ensuring the natural and cultural heritage of a country (Sánchez-Azofeifa et al. 1999; Forero-Medina and Joppa 2010), and these protected landscapes aim at safeguarding both natural and cultural elements that are representative of a particular region (Davey 1998; Loucks et al. 2008; Forero-Medina and Joppa 2010; Roncancio-Duque and Vélez Vanegas 2019). Previous efforts have contributed to recognising that PAs play an important role in maintaining patterns of land use and biodiversity, which contributes to social aspects and in the preservation of various species and cultural characteristics (Olmos Martínez et al. 2013); PAs are critical for the provision of environmental goods and services, while safeguarding critical habitats for the maintenance of species (Armstrong et al. 2007; Luck et al. 2009; Ferraro et al. 2011).

Colombia is considered the sixth country with the highest mammal richness worldwide, with about 530 species (Ramírez-Chaves et al. 2019). Of these, 236 species are confirmed for the Cundinamarca Department (Lemus-Mejía 2021). Despite this large number of mammal species, there is minimal information on integrating these species into the different management plans or conservation strategies applied in the areas set aside for this purpose (Sánchez et al. 2004). PAs and the landscapes in which they are located, have been affected in recent decades by the increase of various stressors that directly affect biodiversity. Some of the main stressors identified for Colombia include deforestation, agriculture, poaching, presence of exotic invasive species, among others (Parques Nacionales Naturales de Colombia 2021); all these have a great effect on biodiversity and are now included as targets and priorities in different plans for their mitigation. At the national level, about 9.6% of the total area of the National System of Protected Areas (**SINAP**) has been transformed (IDEAM et al. 2017). This, coupled with the increasing rate of deforestation (Clerici et al. 2020), seriously affects the ecological processes on which species and ecosystems depend. Added to this, pressures associated with the drivers of global change, such as the unsustainable use of natural resources, the increase in the presence and abundance of invasive species and the challenges imposed by climate change, seriously affect the habitats of most species (Guerra et al. 2019; Clerici et al. 2020; Harfoot et al. 2021; Murillo-Sandoval et al. 2021). Likewise, the direct pressures generated by the increasing use of resources and territory, due to accelerated demographic growth, generate the expansion of more urban areas (Alberti and Marzluff 2004; Etter et al. 2008; Curtis et al. 2018), reflecting on the intensity generated by the anthropogenic impact on terrestrial ecosystems where the human contribution is increasing (Sanderson et al. 2002; Correa Ayram et al. 2020).

This trend, associated with the increase in biodiversity loss stressors, generates an urgency for the conservation and management of species and their habitats, especially those subject to direct use (Bogoni et al. 2020; Green et al. 2020; Nickel et al. 2020). To better design management and conservation strategies for species, it is vital to un-

derstand the potential effect that the transformation of ecosystems and human actions has on the habitats and distribution areas of the species (Bogoni et al. 2020). Correa Ayram et al. (2020), through the multitemporal analysis of the Human Spatial Footprint Index (a measure that assesses the human impact on ecosystems derived from multiple variables), managed to identify that, in the last 45 years, the impact, or the magnitude of the human footprint, has increased by 50% in Colombia, with the Caribbean and the Andes being the regions where this increase has been greater. Likewise, they evaluated the future trend and predicted that, if there is no change in the pattern of use, by the year 2030, the Human Spatial Footprint Index will have increased by 12% more. In addition, approximately 65% of the land has already been subject of transformation processes (Correa Ayram et al. 2020). Specifically for the Andean Region, current values of the HSFI are estimated as high (Fig. 1A) and this has reflected on decreasing wealth of local or regional fauna (Etter and van Wyngaarden 2000; Etter et al. 2006) and triggered concentration of species populations to the small vegetation fragments that remain relatively intact (Armenteras et al. 2003; Cortés-Delgado and Pérez-Torres 2011; Magioli et al. 2021).

Here, we evaluated the representation of mammals in PAs and the magnitude of the human influence over the range of mammal species subject to use in the Cundinamarca Department and whether this influence is less significant within PAs. For this purpose, we developed three specific objectives: i) to analyse the representation of mammal species subject to use within the current PAs system, ii) to evaluate the magnitude of human influence, using the Human Spatial Footprint Index (HSFI) approach, across the range of all mammals subject to use inside and outside PAs and iii) to identify differences in the magnitude of human influence according to representation and different level of threat.

Materials and methods

Study area

The study area comprised the Cundinamarca Department (political division homologous to states), located in central Colombia, in the Andean Region (Fig. 1). Cundinamarca is the most populated Department in Colombia and includes the country's capital city. The Department has an average altitude of 3,341 m a.s.l., a total area of 24,210 km² distributed in 116 municipalities with 2,919,060 inhabitants without considering the capital city's population (7,743,955 inhabitants) (DANE 2019). Being one of the most populated regions also presents one of the highest levels of transformation (Fig. 1A). The Department includes 184 protected areas distributed in 73 of the national or regional level and 111 private reserves of the civil society, covering 315,894.45 hectares; many of these areas are very small (mean area of 41.6 ha) and scattered through the Department (RUNAP 2019) (Fig. 1B).

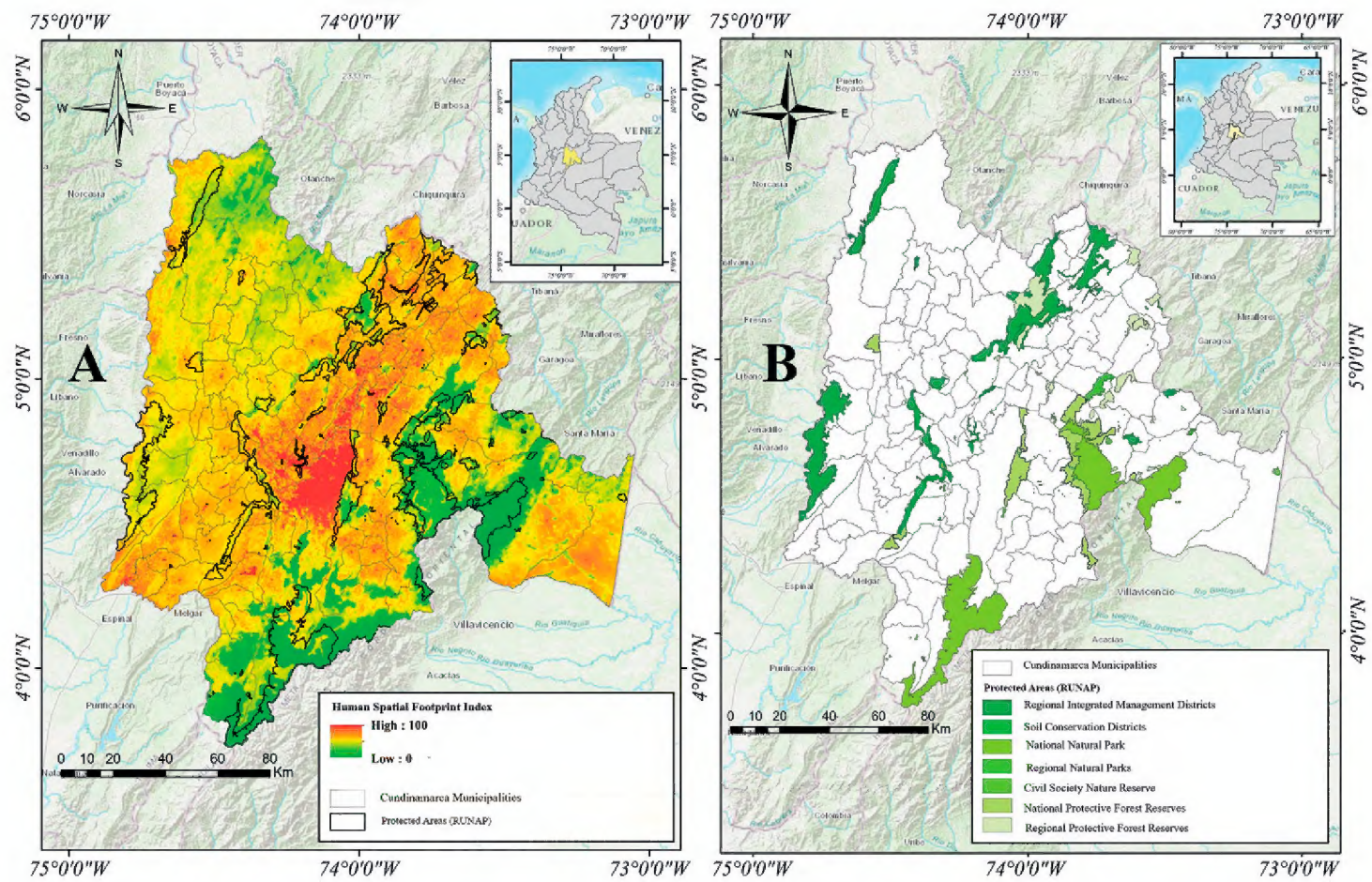


Figure 1. Human Footprint and Protected areas in Cundinamarca **A** representation of the Human Spatial Footprint Index and **B** location of Protected Areas in the Department of Cundinamarca, Colombia. PA categories are based on the national classification.

Species selection

In our study, we analysed the current human influence within the potential distribution range of mammal species used by local communities. The definition of species used by local communities refers to using a resource for economic, religious and traditional values governed by social, cultural and economic trends (Racero-Casarrubia et al. 2008; Cunha-Ribeiro and Schiavetty 2009). These species are used as the study object because they can generate, in the short term, a greater impact on the well-being of local communities; if their abundance or presence is affected, it will have a direct effect on ecosystems and their services, thus affecting human well-being. For all species confirmed in the Department (González-Maya et al. 2021b; Lemus-Mejía 2021), we conducted a bibliographic search for their potential social and cultural uses worldwide (e.g. food, medicine, economy, religion and others). Specifically, we searched for all reported uses on multiple databases, including the IUCN Red List of Threatened Species (IUCN 2018) and complemented with local and regional literature available on multiple databases (i.e. Google Scholar, Web of Science, SCOPUS, among others.). We used Boolean operators (AND, OR and NOT) creating different searching equations that combine the colloquial and scientific name of each species with words, such as “Food”, “Pet”, “Control”, “Subproducts”, “Medicine” and any synonym of these words that may lead to finding information about the possible uses of the species. This first lit-

erature search was a basic approximation to make the first filter on the species that were considered as subject of use. Complementarily, we conducted interviews across the Department to survey potential uses for the entire species list. The interviewed people were from 20 municipalities of the Department, all identified as areas of high vulnerability due to presence of forest remnants and high species richness combined with high levels of human transformation. We conducted a semi-structured interview including a visual guide of species potentially present in the area and the different types of uses (Barbosa Camargo 2020), amongst other questions related to the perception of changes in their abundance, conflict, amongst others. In order to characterise the type of use or value that communities give to each species, we interviewed about the type of relationship that each interviewee considered to have with each of these species. The relationship could vary from conflict events and retaliatory killing to direct consumption, commercialisation, use of it as products, medicine, contemplation or any other cultural relationship (Castaño-Uribe et al. 2013; Ministerio de Ambiente y Desarrollo Sostenible and Fundación Omacha 2016; Tinoco-Sotomayor et al. 2021).

To secure a representative sample size, we defined the number of interviews for each locality according to the extension of each municipality and the human population census for 2018 (DANE 2019). Based on the corresponding number of interviews for each municipality, we identified cells with forest assuming the presence of wildlife and the potential use by the communities; thus, we located core areas where we conducted the interviews. From February to March 2020, we conducted 200 interviews in over 120 villages of 20 prioritised municipalities and to people ranging between 15 and 70 years of age and with at least six months of residence in the area.

We then categorised each mammal species according to four use categories: Food, defined as any direct consumption of a mammal; Pet/Traffic, defined as any report of direct use as a pet or subject to illegal traffic for multiple purposes; Control, defined as those species subject to retaliatory killing, usually due to previous conflict or considered as a “pest” and; Subproducts, defined as those species used whole or their parts for the production of a secondary product (Osbaahr and Morales 2012; Castaño-Uribe et al. 2013; Barbosa Camargo 2020). Furthermore, we categorised each species according to its international conservation status, following the IUCN Red List of Threatened Species Categories and Criteria (Critically Endangered (**CR**), Endangered (**EN**), Vulnerable (**VU**), Near Threatened (**NT**), Least Concern (**LC**), Data Deficient (**DD**) or Not Evaluated (**NE**)).

Potential distribution and representation

We estimated representation as the percentage of potential distribution, or range extension, of a species that is currently protected or included by existing PAs (González-Maya et al. 2015; House et al. 2017). In order to have a range for each species, we based our analysis on models for all species (González-Maya et al. 2021b; Lemus-Mejía 2021), based on an ecological niche modelling approach (Peterson et al. 2011). In order to create distribution models for all species, we constructed a database composed

of historical and current records for the 236 mammalian species confirmed for the Department of Cundinamarca (González-Maya et al. 2021b; Lemus-Mejía 2021); records were obtained from different sources, such as biological collections and published and grey scientific literature available in the country (Zárrate-Charry 2018; González-Maya et al. 2021b (i.e. SIB Colombia, VertNet, GBIF). To construct species distributions, we used the occurrence records that passed a quality filter and a spatial filter thinning, focusing our analysis on species with 20 or more records (Lemus-Mejía 2021), thus securing a better distribution hypothesis. We used a set of bioclimatic variables (Fick and Hijmans 2017) with a 1 km² resolution: Bio1 (Annual Mean Temperature), Bio2 (Mean Diurnal Range), Bio4 (Temperature Seasonality), Bio12 (Annual Precipitation) and Bio15 (Precipitation Seasonality). The variables Bio13 (Precipitation of the Wettest Month), Bio14 (Precipitation of the Driest Month) and elevation (Instituto Geográfico Agustín Codazzi 2016) were additionally included since the first two could reflect the ENSO (El Niño-Southern Oscillation) phenomenon and the third is considered a proxy for variables, such as radiation and oxygen concentration (Burneo et al. 2009). We developed potential distribution models using RStudio Desktop 1.4.1106 (R Team Development Core 2019) and the Wallace package (Kass et al. 2018). Details on the modelling approach and the specific models constructed for our analyses are also available elsewhere (González-Maya et al. 2021b; Lemus-Mejía 2021). A total of 30 models for each species were created (Lemus-Mejía 2021) using six different values of Regularisation Multipliers (RM; 0.5–3 in intervals of 0.5), five Feature Classes (FC) combinations (linear = **L**, linear-quadratic = **LQ**, hinge = **H**, linear-quadratic-hinge = **LQH** and linear-quadratic-hinge-product = **LQHP**), with 10,000 background points. The best models for each species were selected from the AUC test and the AICc Delta value (Zárrate-Charry et al. 2018). We then compared the areas covered by the binary representation of the species distribution model with the most updated polygon of all PAs in the Department (RUNAP 2019). A representation value was estimated for each species, including the total area of the Department covered by the potential distribution and the percentage of the range included in PAs and, likewise, the average representation value of the total species within the Department. Additionally, we compared representation values for species categorised under any threat category and non-threatened species using a Mann Whitney U test. Furthermore, considering that different types of uses represent differential pressures for each species, according with the type of use, we compared the representation between types of uses and within each type of use using a Kruskal-Wallis non-parametric test.

Human influence on landscapes (Human Spatial Footprint Index-HSFI)

To evaluate the human influence over each mammal species subject to use, we used the most updated Human Spatial Footprint Index (HSFI) for the country with an accuracy of 300 m² (Correa Ayram et al. 2020). This Index shows a spatial representation of the cumulative impact that human pressures have on the environment (Venter et al. 2016). The human footprint measures directly, through spatial data, the impact

on demand and consumption that humans have on Earth and human practices that are significantly reducing the resilience or recovery capacity of ecosystems causing irreversible effects on diversity, such as local extinction of species (Correa Ayram et al. 2017). The three dimensions assessed are soil intensity, time of anthropogenic intervention and biophysical vulnerability (Correa Ayram et al. 2020). This Index has been widely used to assess landscape changes and humans' potential impact on both species' habitat and connectivity (Nori et al. 2015; Correa Ayram et al. 2017). We overlapped the Human Spatial Footprint Index (**HSFI**) with the potential distribution areas of all species. This process allowed us to obtain a layer of values associated with the HSFI for each species, calculating a mean value and a standard deviation of the HSFI for each species for the whole Department. We then evaluated the mean value of the HSFI for the orders to identify potential groups that present a greater vulnerability due to the low quality of their distribution areas and due to the high values of human impacts. To evaluate the role that PAs can play for maintaining quality habitats for all species, we performed an evaluation of the mean value of the HSFI within the PA and contrasted these values with the total HSFI value of its distribution area; we used a t-paired test to explore if statistically significant differences existed between HSFI values in and out Protected Areas. This procedure also allowed obtaining a mean value ($\pm$ SD) to understand the degree of human influence present in species distribution within PAs. The Human Spatial Footprint Index values are presented from 0 to 100, with 0 being the areas considered "natural" and 100 the areas with the maximum value of Human Footprint or anthropogenic impact (Correa Ayram et al. 2020). Finally, we compared the HSFI overall for the Department and within PAs between types of uses and within each type of use, using a Kruskal-Wallis non-parametric test.

All geographic analyses were performed using ArcGIS 10.x (Environmental Systems Research Institute 2016) and all statistical analyses were performed in R language (R Team Development Core 2021).

Results

We identified 43 species subject to use for the Department, mostly associated with direct use, but with some others related to cultural and religious uses (Table 1). Of the total 43 species subject to use in the Department, nine are threatened according to the IUCN Red List of Threatened Species and 10 are threatened according to the country's national legislation. Carnivora was the order with the highest number of species analysed with 16 (37.21%), followed by the order Primates with seven, Rodentia with six and Pilosa with five (16.28%, 13.95% and 11.63%, respectively; Table 1).

Distribution of species richness showed an important concentration of species for the lowlands bordering the Magdalena River, on the western flank of the eastern range of the Andes (Fig. 2). The mean value of representation within PAs for all species was lower than the global representation goals (17%; Aichi targets; Gannon et al. 2019) and, in general, is considered under most national goals (Mean $\pm$ SD = $10.69 \pm 4.99\%$; Fig. 3).

Table 1. Mammals subject to use identified for the Department of Cundinamarca, Colombia, including the type of use reported.

Order	Species	Common name	IUCN Cat.	Use reported			
				Food	Pet/ Traffic	Control	Subprod- ucts
Artiodactyla	<i>Mazama rufina</i>	Dwarf red brocket	VU	X		X	X
	<i>Pecari tajacu</i>	Collared peccary	LC	X	X	X	X
Carnivora	<i>Cerdocyon thous</i>	Crab-eating fox	LC				X
	<i>Eira barbara</i>	Tayra	LC			X	X
	<i>Herpailurus yagouaroundi</i>	Yaguarundi	LC		X	X	
	<i>Leopardus pardalis</i>	Ocelot	LC		X		X
	<i>Leopardus tigrinus</i>	Oncilla	VU		X		X
	<i>Leopardus wiedii</i>	Margay	NT		X		X
	<i>Lontra longicaudis</i>	Neotropical otter	NT			X	X
	<i>Mustela frenata</i>	Long-tailed weasel	LC				X
	<i>Nasua nasua</i>	South American coati	LC	X	X	X	X
	<i>Nasuella olivacea</i>	Western mountain coati	NT	X	X		X
	<i>Panthera onca</i>	Jaguar	NT	X	X	X	X
	<i>Potos flavus</i>	Kinkajou	LC	X	X		X
	<i>Procyon cancrivorus</i>	Crab-eating raccoon	LC		X		X
	<i>Puma concolor</i>	Puma	LC		X	X	X
	<i>Tremarctos ornatus</i>	Spectacled bear	VU	X	X		X
	<i>Urocyon cinereoargenteus</i>	Grey fox	LC		X	X	X
Chiroptera	<i>Desmodus rotundus</i>	Vampire bat	LC			X	X
	<i>Myotis nigricans</i>		LC			X	
Cingulata	<i>Dasypus novemcinctus</i>	Nine-banded armadillo	LC	X	X		X
	<i>Cabassous centralis</i>	Naked-tailed armadillo	LC	X			X
Didelphimorphia	<i>Caluromys lanatus</i>	Brown-eared woolly opossum	LC				X
	<i>Chironectes minimus</i>	Water opossum	LC				X
	<i>Didelphis marsupialis</i>	Common opossum	LC	X		X	X
Pilosa	<i>Bradypus variegatus</i>	Three-toed sloth	LC	X	X		X
	<i>Choloepus hoffmanni</i>	Hoffmann's two-toed sloth	LC	X	X		
	<i>Myrmecophaga tridactyla</i>	Giant anteater	VU	X	X	X	X
	<i>Tamandua mexicana</i>	Northern tamandua	LC	X	X		
	<i>Tamandua tetradactyla</i>	Southern tamandua	LC			X	X
Primates	<i>Alouatta seniculus</i>	Colombian red howler monkey	LC	X			X
	<i>Aotus griseimembra</i>	Grey-handed night monkey	VU	X	X		
	<i>Ateles belzebuth</i>	White-bellied spider monkey	EN	X	X		
	<i>Lagothrix lagotricha</i>	Common woolly monkey	VU	X	X	X	X
	<i>Saguinus leucopus</i>	Silvery-brown tamarin	EN		X		
	<i>Saimiri sciureus</i>	Guianan squirrel monkey	LC		X		
	<i>Sapajus apella</i>	Black-capped capuchin	LC	X	X		
	<i>Cavia aperea</i>	Brazilian guinea pig	LC	X			
Rodentia	<i>Cuniculus paca</i>	Agouti	LC	X	X		
	<i>Cuniculus taczanowskii</i>	Mountain paca	NT	X		X	
	<i>Dasyprocta fuliginosa</i>	Black agouti	LC	X			
	<i>Dasyprocta punctata</i>	Central American agouti	LC	X			
	<i>Hydrochoerus hydrochaeris</i>	Capybara	LC	X	X	X	X

More than half of the species presented in the analysis have a representation value lower than 10%, with the rest of their ranges being outside PAs (Fig. 3). Orders with the lowest mean representation value are the order Pilosa and Didelphimorphia (Mean $\pm$ SD = $7.21 \pm 4.44\%$ and $7.626 \pm 1.37\%$, respectively), while Carnivora and Artiodactyla showed

the highest mean representativity (Mean $\pm$ SD = 13.61 $\pm$ 4.70% and 13.63 $\pm$ 9.92%, respectively). The order Pilosa contained the species with the lowest PA representation in the whole study, the anteater (*Tamandua tetradactyla*), a species that, besides being under-represented, has a very small distribution area in the jurisdiction of the Department.

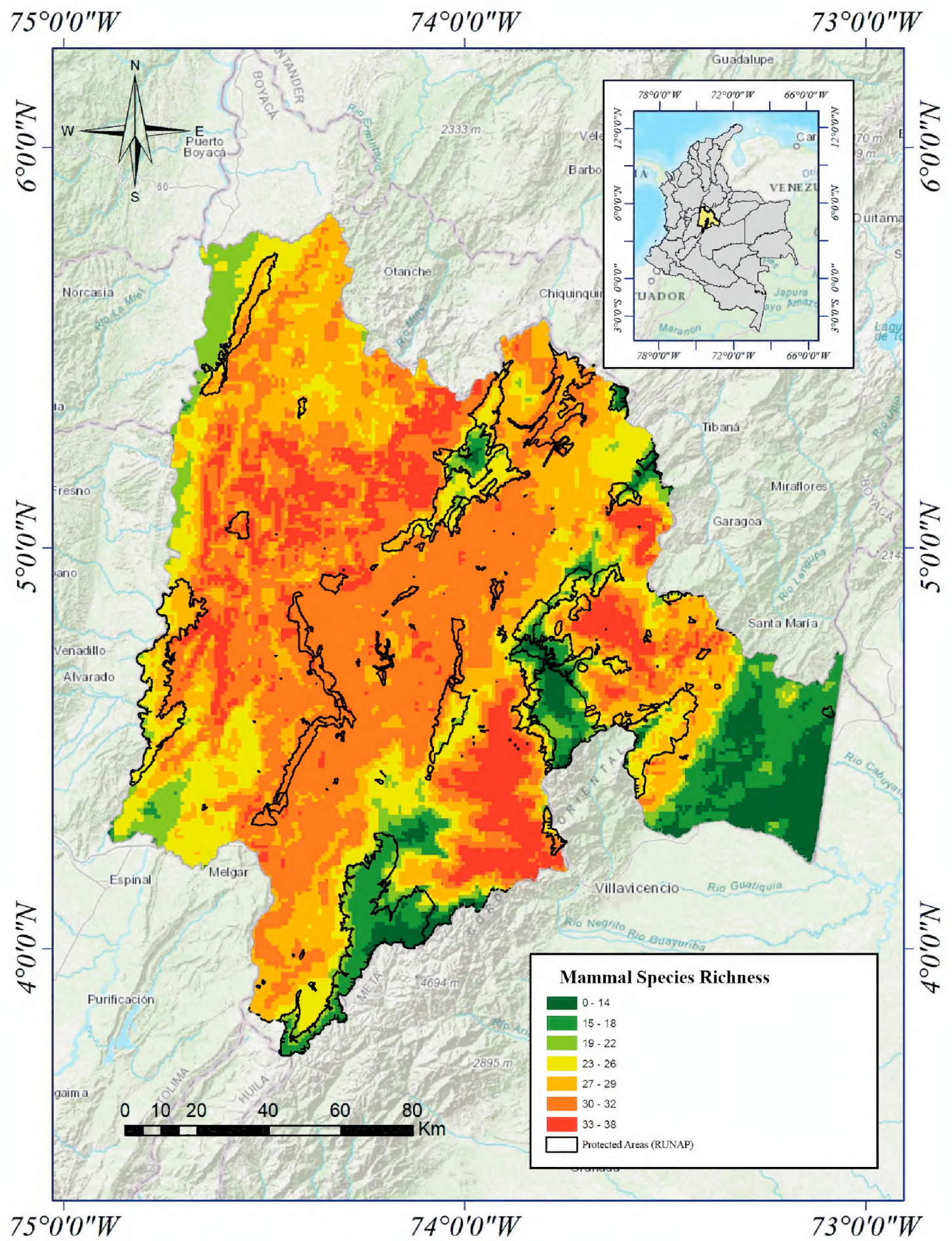


Figure 2. Mammal species richness. Potential distribution of species richness of mammals subject to use in the Department of Cundinamarca, Colombia, with a resolution of 1 km.

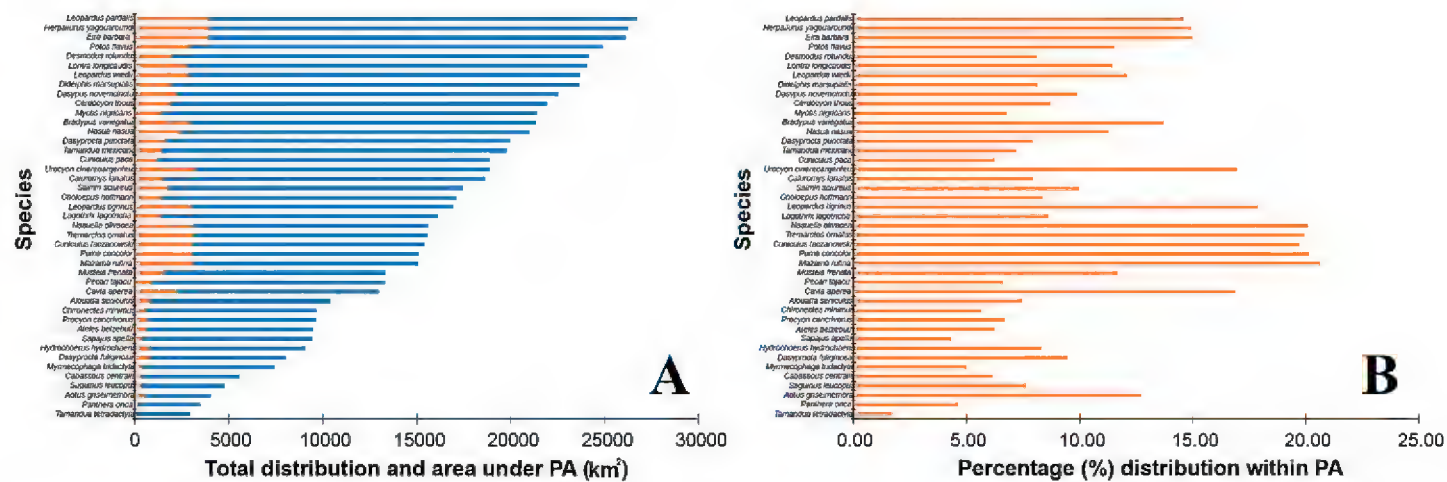


Figure 3. Distribution and representation of mammals in PAs **A** Total distribution and area under Protected Areas values and **B** representation (%) within PAs for all mammal species subject to use in the Department of Cundinamarca, Colombia.

In terms of species under any risk category, mean representation was significantly lower than for the non-threatened species (69.91 vs. 46.19%; $W = 105.00$, $p = 0.026$). Of these species, the Jaguar (*Panthera onca*) has the lowest representation for the Department (4.64%). The mean value ($\pm$ SD) of the Human Spatial Footprint Index (HSFI) for the distribution areas of all species was $57.08 (\pm 2.74)$. This is a medium value, but it is very close to values considered high according to the HSFI, which are those over 60. We found very few species with areas with HSFI values lower than 40, which means that there are no areas that could be considered with low footprint values (Fig. 4).

Although for most of the Department of Cundinamarca, HSFI values are high or medium, within the PAs, the values are lower, which is evident in PAs such as

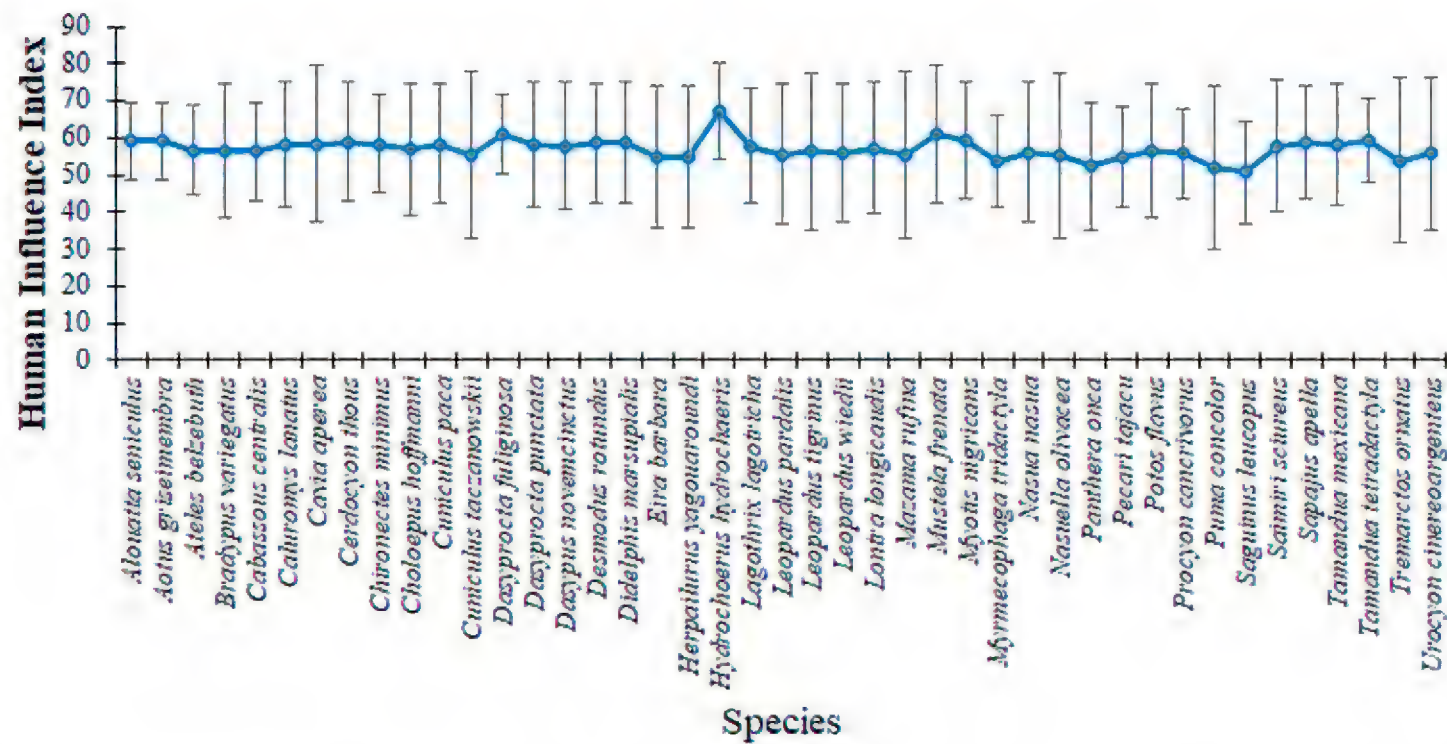


Figure 4. Mean Human Spatial Footprint Index within mammal ranges. Distribution and mean value of the Human Spatial Footprint Index (HSFI) for mammal species subject to use within the Department of Cundinamarca, Colombia.

Chingaza National Natural Park, the Cuchillas Negra and Guanaque and Cuchilla San Cayetano Integrated Management Regional Districts and the multiple protective forest reserves in the areas near Chingaza. In order to demonstrate whether PAs are ensuring habitat quality within the distribution of mammal species subject to use, we compared mean values of the HSFI of the distribution of the species in unprotected areas of the Cundinamarca Department and the mean value within all PAs. We found statistically significant differences ($T = 11.74$, $p < 0.01$) where almost all species have higher HSFI values throughout the Department than in PAs. On average, there is a difference of 10.72 points between the average HSFI of the Department and that of the PAs ($\text{Mean} \pm \text{SD} = 10.73 \pm 5.98\%$). This shows that the state of the species' habitats is less impacted by human activities within PAs and that the conservation areas of most species depend, to a large extent, on them (Fig. 5).

Finally, when including the type of use and considering the differential pressure that different types of uses represent for each species, we found slight differences between representation and the level of human intervention on species ranges both in the whole Department and only inside PAs (Fig. 6). When comparing between species with and without use for each type, we only found significant differences for species subject to traffic/use as pets in terms of HSFI in the Department ($H = 3.95$, $p = 0.046$) and within PAs ($H = 5.93$, $p = 0.014$), with those species showing lower levels of intervention (Table 2). No significant differences were found for the rest of uses and for the three variables (Table 2). We found no differences between the types of uses for the three variables for those species subject to use (Table 2).

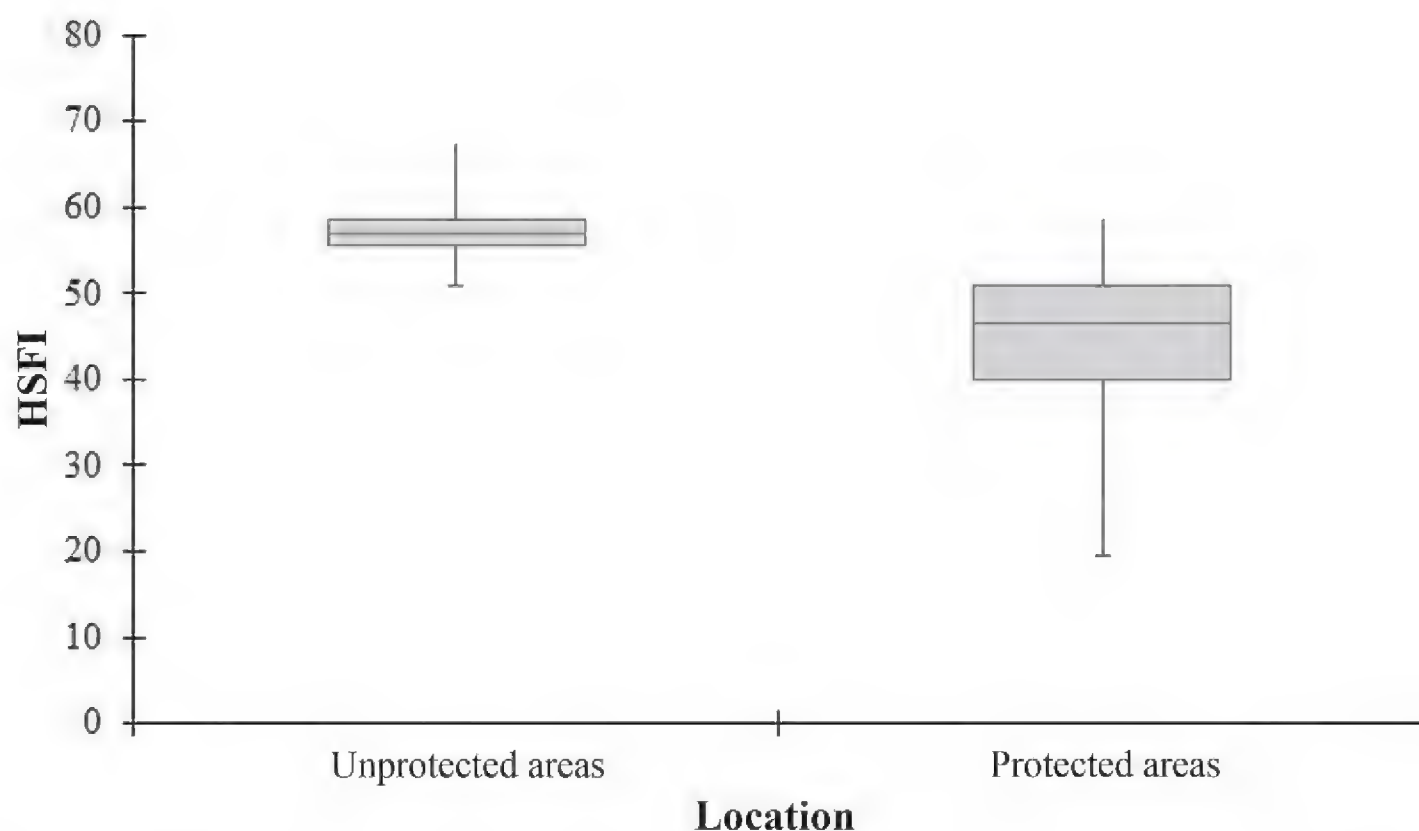


Figure 5. Human Spatial Footprint Index in and out of PAs. Comparison of the mean values of the Human Spatial Footprint Index of the distribution areas of the mammals subject to use inside and outside the PAs of the Department of Cundinamarca, Colombia.

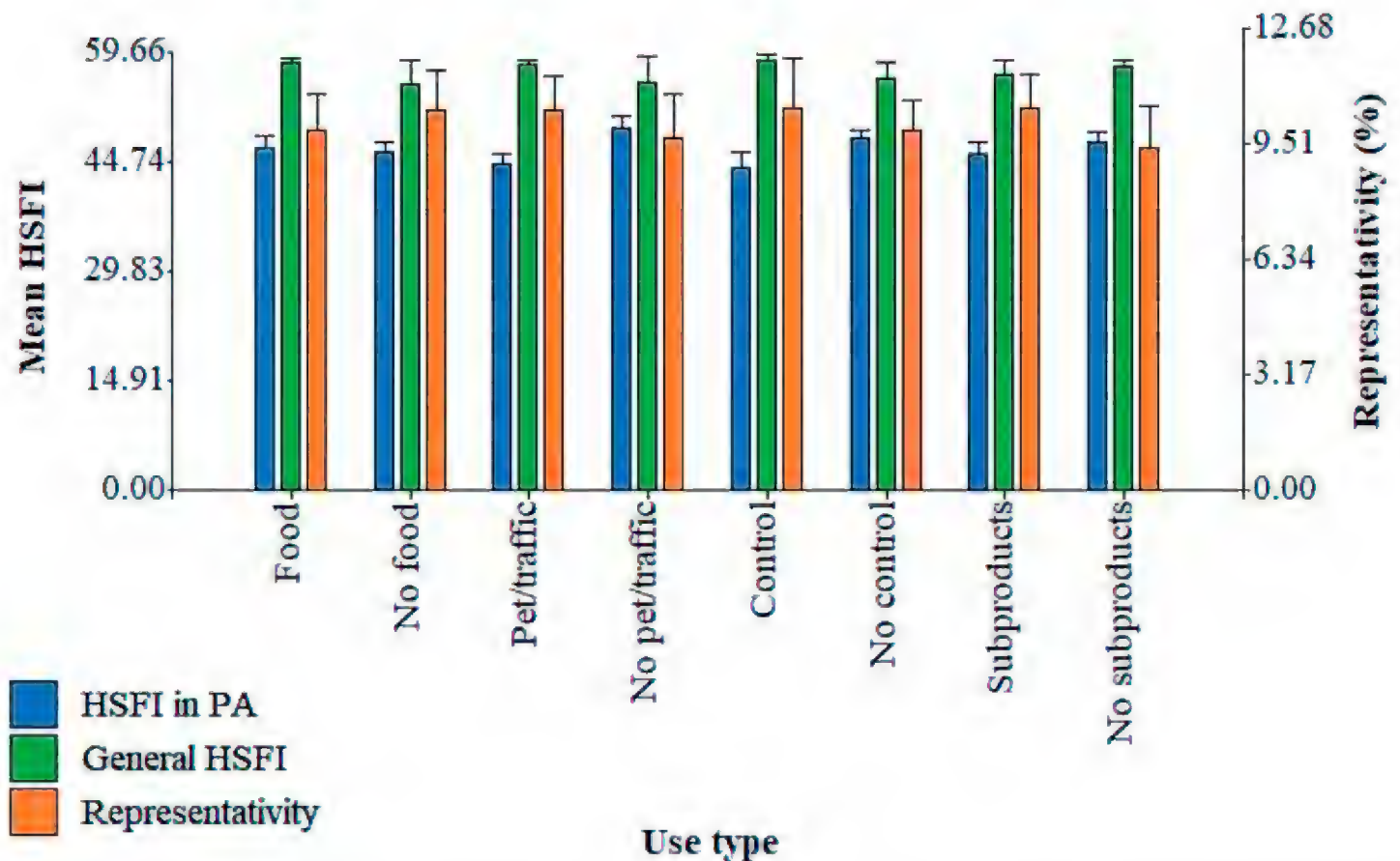


Figure 6. Human Spatial Footprint Index and representation for different species uses. Overall Human Spatial Footprint Index in the Department and within PAs compared with species subject to different types of uses in the Department of Cundinamarca, Colombia. Percentage of representation is on the secondary Y-axis.

Table 2. Comparison between mammal and use and no-use between different use types and for Human Spatial Footprint Index overall for the Department and within protected areas and for representation for the Department of Cundinamarca, Colombia. * Indicates significant differences.

Comparison	Type of use	Variable	H	p
Use / No use	Consumption	Representation	0.555	0.460
		HSFI Department	0.097	0.767
		HSFI in PA	0.059	0.824
	Control	Representation	0.099	0.765
		HSFI Department	1.733	0.188
		HSFI in PA	0.002	0.960
	Pet/traffic	Representation	0.200	0.654
		HSFI Department	3.959	0.040*
		HSFI in PA	5.936	0.014*
	Subproducts	Representation	0.656	0.421
		HSFI Department	0.002	0.9587
		HSFI in PA	0.153	0.697
Between uses	Consumption vs. Control vs. Pet/traffic vs. Subproducts	Representation	0.490	0.921
		HSFI in PA	1.753	0.624
		HSFI Department	1.073	0.783

Discussion

With its wide elevation gradient and mountainous topography, Cundinamarca harbours a wide variety of ecosystems and biodiversity (Conservación Internacional Colombia and Corporación Autónoma Regional de Cundinamarca 2011), even

considered as part of one of the global hotspots: the Tropical Andes (Myers et al. 2000). However, the continuous historic and ongoing land-cover change (Etter and van Wyngaarden 2000; Etter et al. 2006; Correa Ayram et al. 2020), the high impact of human activities and the effects related to global change drivers have affected and will keep affecting biodiversity, in general, and mammals, in particular (Schipper et al. 2008; Correa Ayram et al. 2018; Castillo et al. 2020). Human influence across species ranges is usually conceived as one of the best proxies of species threats and risk, especially for species with a close relationship with humans or those directly affected by their use (Sanderson et al. 2002; Woolmer et al. 2008). Here, we presented one of the first systematic approaches to the effects of human influence on an ecological and culturally important group of species, as a basis for appropriate decision-making and for providing information for conservation.

Most of the species distribution and the correspondent richness values respond to the heterogeneity of the transition zone between the Andes and the lowlands of the inter-Andean valleys of the Magdalena River and the Llanos, both located in the same area of the transformation front and the area where the highest HSFI values are located (Correa Ayram et al. 2020). This is evident in the Department's eastern and western zones in the lower fringe of the mountain range, except for the areas within some PAs, like Chingaza PNN and the various protection figures that surround it (Fig. 3).

More than half of the species presented in the analysis have a representation value lower than 10%, with most of their ranges located outside PAs; therefore, depending to a large extent on actions and management that takes place in private lands, a situation that has been seen before in mammal species, such as jaguar and puma (de la Torre et al. 2017; Zárrate-Charry et al. 2018). Furthermore, no order showed representation values above 15%, which is lower than the global representation targets for elements, such as biomes related to the Aichi targets (Woodley et al. 2012; Bacon et al. 2019). These values are well below other required areas for some groups, such as carnivores, where more ambitious targets such as 30% representation are proposed to ensure their ecological needs (Di Minin et al. 2016). The species with the lowest representation for the Department of Cundinamarca are the southern tamandua (*Tamandua tetradactyla*), the black-capped capuchin (*Sapajus apella*) and the jaguar (*Panthera onca*). Reasons associated with such low representation are likely explained by the restricted distribution of these species in the Department (Alzate-Gaviria et al. 2016; Payán et al. 2016; Olaya-Rodríguez et al. 2020), mostly restricted to the lowland areas, where the distribution of PAs is scarce, as the Department's system of PAs is predominantly montane, located in areas > 2,000 m above sea level (RUNAP 2019). This is especially worrisome for species, such as the black-capped capuchin and the jaguar, since they depend on conserved landscapes or extensive areas with remnant natural habitats and, in both cases, their representation in PAs was below 5%. Remarkably, half of the nine threatened species showed representation values lower than 10%, which represents a significant threat to their survival, especially considering most of their threats are related to habitat loss and degradation which are very high in most of the Department, especially outside

PAs. Overall, the low representation within PAs for most species and the high level of transformation and human impact outside them, indicate the Department retains very unsuitable conditions for most species subject to use and, therefore, the probability of survival for the long term of most species in the Department is likely very low.

Natural cover remnants with good quality and with considerable size in the Department are scarce and poorly represented in PAs, as in most of the Andean Region (Armenteras et al. 2003) and the magnitude of human influence in the entire region is amongst the highest in the country, along with the Caribbean Region (Correa Ayram et al. 2020). Furthermore, given the generalised scarcity of information on the ecology of most species, including their habitat requirements, it is necessary to use other approaches to assess the current status or vulnerability of species through their habitats to increasing pressures related to anthropogenic variables (Collen et al. 2008; Leidig and Teeuw 2015). That is why we evaluated the influence of humans across the range of all mammal species subject to use by means of the Human Spatial Footprint Index (HSFI) and compared the status of species distribution in the Department and inside PAs, in order to evidence whether being inside a PA makes the magnitude of the impact of human pressures lower.

All species subject to use in the Department have a mean value of human influence over their entire distribution higher than 50, which is of particular concern since this value is well over the threshold of high intervention according to the Index (Correa Ayram et al. 2017; Correa Ayram et al. 2018). The two species that showed the mean higher values (> 60) were the long-tailed weasel (*Mustela frenata*) and the capybara (*Hydrochoerus hydrochaeris*). For the long-tailed weasel, for instance, the distribution includes a large part of the central zone of Cundinamarca, including Bogotá, the capital city of Colombia and its surrounding areas, some of the most populated and industrialised regions in the country (Gobernación de Cundinamarca 2020; González-Maya et al. 2021a). In general, the results indicate that human activities overall have fewer impacts over species' habitats within PAs and that the conservation areas for most species depend largely on them (Fig. 4). We found very few species with areas with low (< 30) index values, which means that, for the study area, there are no areas with a low human footprint (Fig. 5). This value is critical for supporting how to design conservation strategies since the existing PAs are not so extensive and have not been designed to ensure the representation of mammal species or, in fact, any other group; this translates in that conservation efforts depend mainly on private and productive areas, but in the Department, these are particularly adverse since they have very high values of human impact. Given that our focal species are already under severe pressure from their close relationship with humans, quality habitat then becomes an even more important aspect to be considered given the synergistic effect of multiple stressors over their populations. Our results should be considered when defining conservation actions or prioritisation processes for restoration or management zones in the Department to ensure at least the best remaining areas within an otherwise significantly transformed landscape.

Conclusions

Human activities have irreparably affected species habitats and the functioning of ecosystems globally, a dynamic that is becoming increasingly pronounced with catastrophic effects for biodiversity (Ceballos et al. 2015; González-Maya et al. 2017). This reality is no different for Cundinamarca, a Department that, like several in the Andean zone, has suffered the greatest impacts related to human activities in the country (Correa Ayram et al. 2018). Based on this reality, the needs and conservation planning for maintaining species is a great challenge, especially when managing species subject to use that possess characteristics that are part of the culture, use and tradition of human communities (Andrade Pérez and Corzo Mora 2011). Protected Areas have historically functioned as the cornerstone of conservation strategies (Stolton and Dudley 2010), being areas where species can exist and survive and, at the same time, function as a source for colonising recovered surrounding areas (Guerra et al. 2019). Currently, in Colombia, the role and importance of PAs are becoming increasingly evident, but the challenges for their maintenance are also increasing and it is urgent to ensure effective management of these areas and the landscapes that contain them (Ospina Moreno et al. 2020).

Our results make evident that the representation of mammal species within the existing PAs is below the globally defined thresholds and well below the requirements that most species may have (Di Minin et al. 2016; Wilson 2016). Likewise, the conservation status of habitats both inside and outside PAs is low and they have been subjected to various human impacts that make the HSFI values very high for the entire Department. Although the impact values associated with the HSFI are lower within PAs, they are not of optimal quality and efforts are required to redirect this trend and achieve landscape conservation and functionality. Currently, the development and planning of a new PA policy (CONPES 450) provide elements to improve the effectiveness and conservation of PAs and, at the same time, ensures that the surrounding landscapes are managed in a way that ensures the functionality of ecological processes and habitat and species connectivity. In the specific case of the mammals of Cundinamarca, this is critical because, to a large extent, their distribution areas and their management are located on private properties outside of conservation zones and only by strengthening management measures, land use plans and defining new conservation strategies can the maintenance of their habitats be warranted.

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